ANTHROPOGENIC BLACK CARBON EMISSIONS IN ICELAND: CONCENTRATIONS OBSERVED IN SNOW AND GLACIER ICE IN SOUTHERN ICELAND

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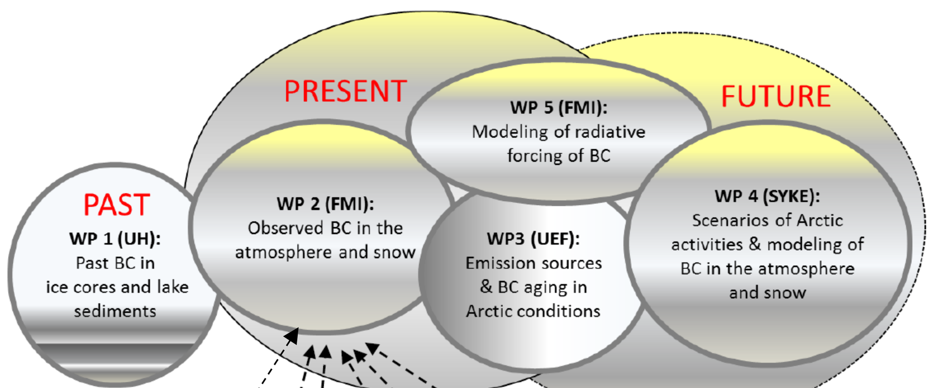
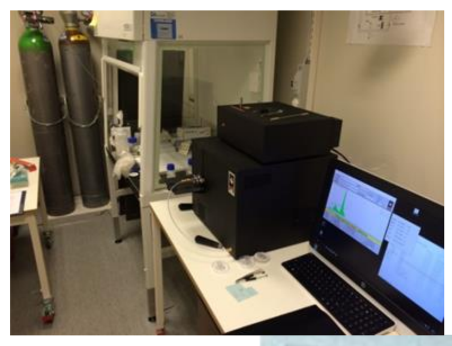
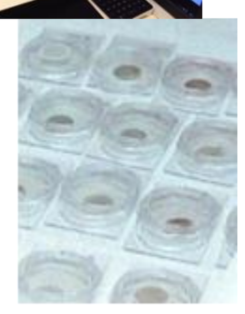
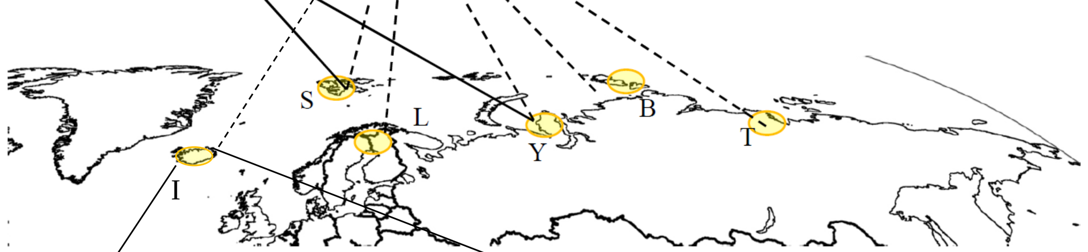
AoF NABCEA-project 2016-2020 on "Novel Assessment of BC"

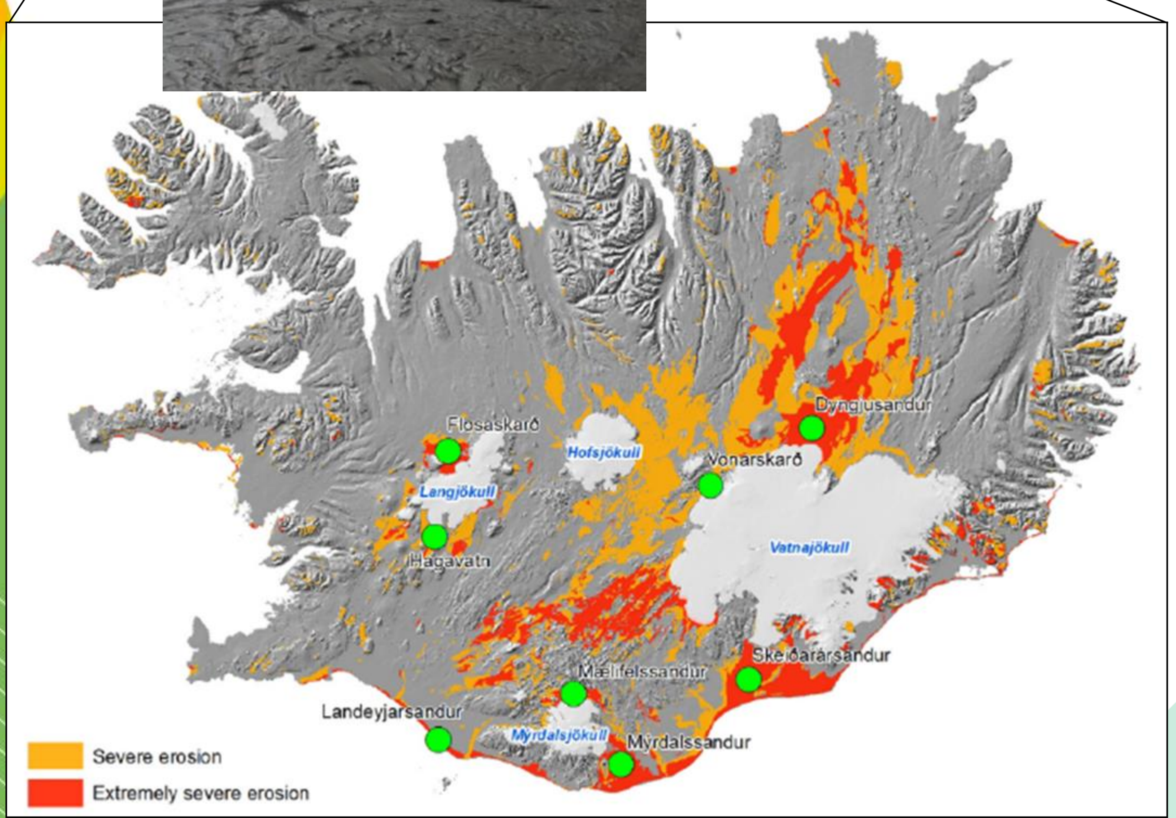








Field measurement sites: S: Svalbard; L: Lapland; Y: Yamal peninsula; B: Bolshevik island; T: Tiksi ; I = Iceland



High Latitude Dust (HLD) sources in Iceland (according to prof. O. Arnalds)

HLD on snow surface clumping mechanism. Our experimental observations (above) were confirmed under natural conditions (right).

BC emissions in Iceland

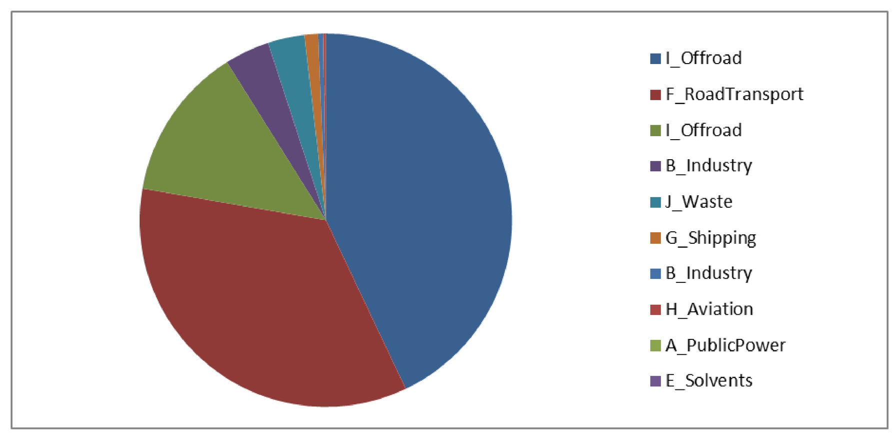
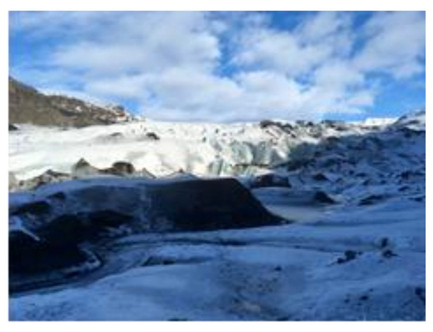


Table below. BC emissions in Iceland based on fuel sold. Calculated on the basis of European Environmental Agency for the emissions, and World Bank for the population data.

Year	National total BC emissions [kt/y]	BC emission per capita [kg/y/capita]
2005	0,1268	0,43
2010	0,1239	0,39
2015	0,1935	0,58

Above: BC emissions in 2015, based on the official CLRTAP national emission inventory of Iceland.

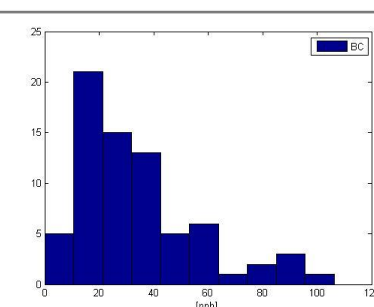
BC in snow and ice in Iceland vs Arctic Finland



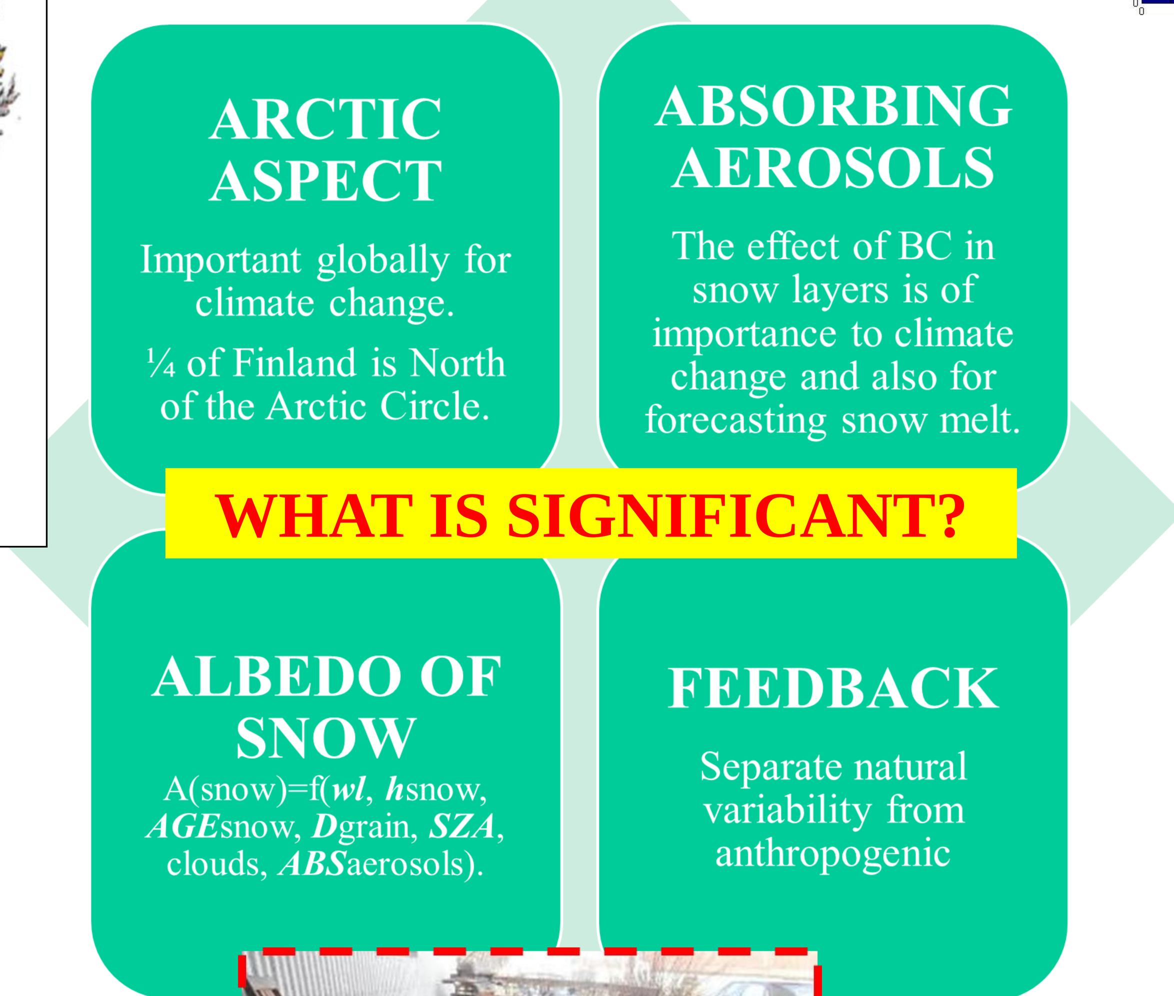
BC in snow and ice in Iceland (new unpublished data).

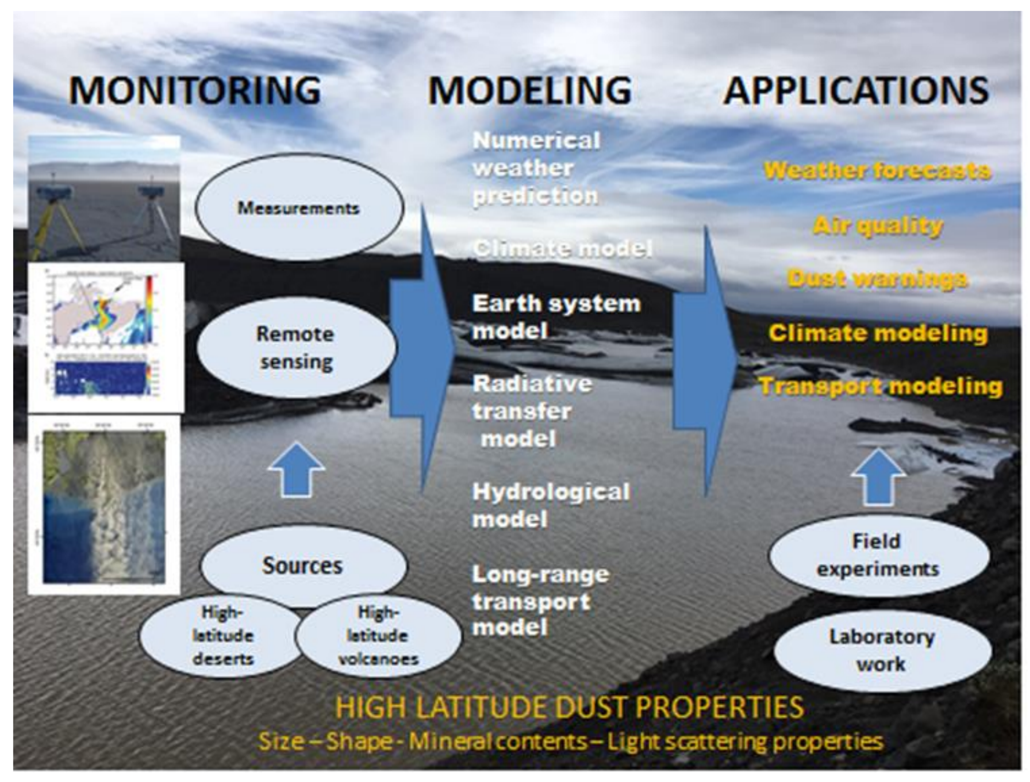
Year	EC in glacier [ppb]	EC closer roads [ppb]
2016	< 12	< 203 (old snow)
2017	< 4	< 70 (new snow)

Above: i) FMI's Thermal/Optical Carbon Aerosol Analyzer (OC/EC), and ii) micro-quartz filters of snow and ice samples. iii) The Solheimajökull glacier surface snow and ice were sampled in 2016 and 2017 in Iceland.

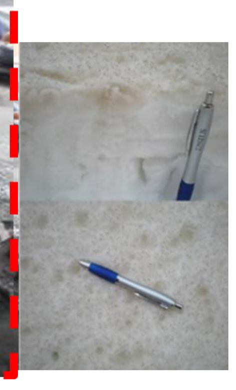


Left: BC in snow in Sodankylä 2009-2011. Based on Table of Meinander et al. ACP 2013. **Above:** During snow melt, observed *soot on snow* clumping mechanism and impurities remaining on the snow surface (SoS-experiment), supported by multiannual seasonal *in situ* snow sampling with increased BC in spring (hydrophobic particles).





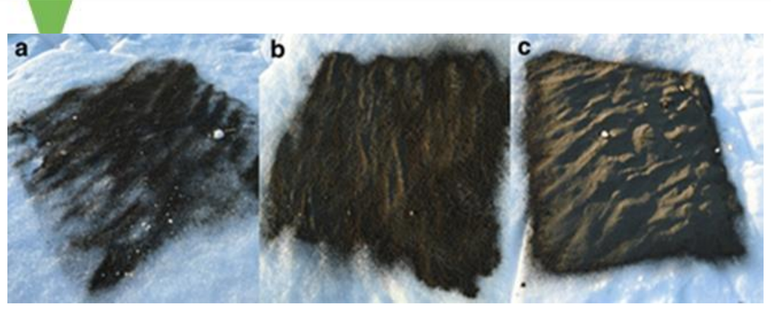
High latitude dust (HLD) particles, **resuspended mineral dust and ash,** originate from natural sources, but deforestation is one of the human actions increasing Arctic deserts and leading to dust events. HLD Arctic assessment is currently missing. Our studies and scientific papers aim to fulfill this gap. E.g., see Dagsson-Waldhauserova et al., Meinander et al., Peltoniemi et al.



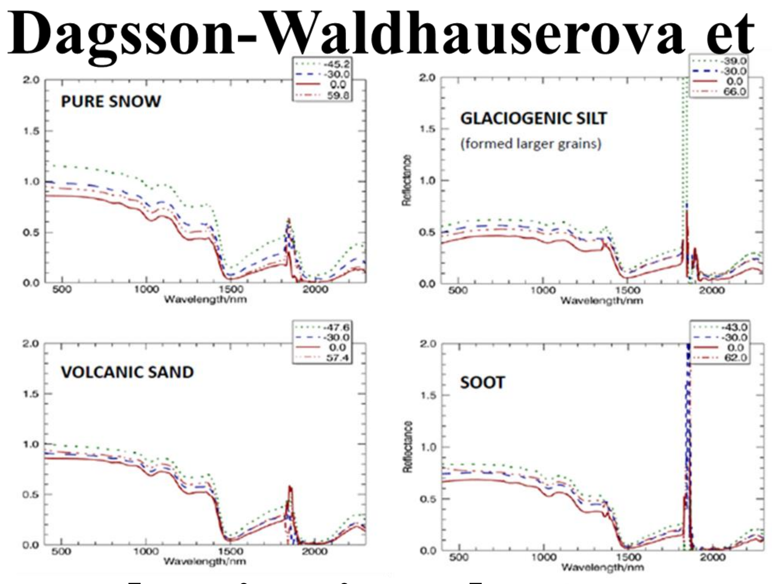
Dagsson-Waldhauserova et al.

Melt or insulation of snow and ice?

Material	Effective thickness [mm]	Critical thickness [mm]
Mt St Helens (1980) ash	3	24
Hekla (1947) tephra	2	5.5
Rock debris	~10	~15–50
Villarrica tephra	-	< 5
Dust (largely organic matter)	-	1.33
Eyjafjällajökull ash (2010, 1 ϕ)	*1*	*9–15*
Eyjafjällajökull ash (2010, 3.5 ϕ)	*≤ 1–2*	*13*



Dragosics et al. 2016



Peltoniemi et al. 2015

Density effect of BC (Meinander et al., TC, 2014)

Soot can decrease the water holding capacity of melting snow and decrease snow density

Explained by:

1. A semi-direct effect of absorbing impurities. -> melt and/or evaporation (liquid phase snow) and sublimation (solid phase snow) -> air pockets around the impurities -> lower snow density

2. BC effecting on the adhesion between liquid water and snow grains. BC reduces adhesion -> the liquid water holding capacity decreases

3. BC effecting on the snow grain size. Absorbing impurities -> increased melting and metamorphosis processes -> larger snow grains -> lower water retention capacity.

CONCLUSIONS: In Iceland, to assess the impacts of light absorbing impurities (LAI) in the cryosphere, it is critical to include all the various LAIs of BC, OC and dust, and processes related to them. *Table (right)*. The cryospheric "density effect" and "melt/insulation effect" of aerosols deposited on snow and ice, as published first based on the experiments of FMI, and independent papers confirming our findings and citing us.

Cryospheric effect	Impurity	First suggested in	Cited and supported in
Density effect	BC	Meinander et al. 2014	Skiles & Painter 2016
Melt/insulation	Eyjafjällajokull dust	Dragosics, Meinander, et al. 2016	Möller et al. 2016

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References: ***Dagsson-Waldhauserova*** et al. Snow-Dust Storm: Unique case study from Iceland, March 6-7, 2013. Aeolian Research 2015. ***Dragosics*** M, Meinander O., Jónsdóttír T.,Dürig T., De Leeuw G., Pálsson F., Dagsson-Waldhauserová P., Thorsteinsson T. Insulation effects of Icelandic dust and volcanic ash on snow and ice. *Arabian Journal of Geosciences*, 9, 126, 2016. ***Meinander*** et al. Spectral albedo of seasonal snow during intensive melt period at Sodankylä, beyond the Arctic Circle, ACP 2013. ***Meinander*** et al. Brief communication: Light-absorbing impurities can reduce the density of melting snow, The Cryosphere 2014. ***Möller***, R., Möller, M., Kukla, P. A., and Schneider, C.: Impact of supraglacial deposits of tephra from Grimsvötn volcano, Iceland, on glacier ablation, J. Glaciol., 62, 933–943, doi:10.1017/jog.2016.82, 2016. ***Peltoniemi*** et al. Soot on Snow experiment: bidirectional reflectance factor measurements of contaminated snow, The Cryosphere 2015. ***Skiles*** SMK & T Painter, Daily evolution in dust and black carbon content, snow grain size, and snow albedo during snowmelt, Rocky Mountains, Colorado, J. Glaciol., 63, 237, 118-132, doi:10.1017/jog.2016.125, 2017.